1. Measurement of sonic speed in air and metal

classification: physics lesson in secondary degree 1, preferred from the 8th class on

complexity of set-up: easy ☐☒☐☐☐ complex

students experiment possible: Yes

objective target/specifics: The determination of sonic speed is an experiment, which is found in nearly all schoolbooks of secondary degree 1. Mainly the effort for chronometry is problematic. The experiment is performed classical with two microphones, which receive the sound signals at different point in time by positioning. Sonic speed can be calculated by the distance of microphones and difference of running time. In this experiment initiation of sound and the arrival at the micro is recorded by CBL2. Sonic speed can be determined by distance and runtime. In contrast to experiments with two microphones this set-up can also be used for determining sonic speed of metals.

needed materials:
diverse rods / tripods, specially a long iron rod(>90cm)
4,5 volt block battery
cable and alligator clips
CBL2
CBL–micro
CBL–voltmeter (supplied clips)
alternative: **TI83plus**; TI84plus; TI92+; TI89; **TI Voyage 200**

circumference of depiction:

1.1a Measurement of sonic speed in the air – information

1.1b Measurement of sonic speed in the air - example
1.2a Measurement of sonic speed in metals - information
1.2b Measurement of sonic speed in metals – example

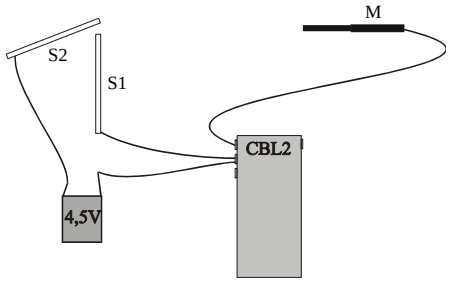
1.3a Measurement of sonic speed in the air - students material (1)

1.3b Measurement of sonic speed in the air - students material (2)

1.4a Public address at big concerts
1.4b Clinical diagnosis of trees

1.1a Measurement of sonic speed in the air – information

schematic set-up

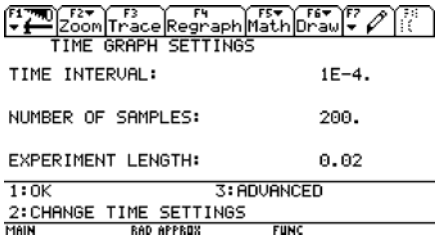


progression of experiment

An electric circuit is built by voltage sensor with two rods (S1 und S2), block battery and the CBL2 (channel 2). The sound (bang) is produced by the student, who smashes with the rod (S1) against rod (S2). Closing the electric circuit you can measure voltage at CBL 2. The experiment can be started by triggering the measured voltage. The micro records sound signals parallel to voltage. To communicate with the CBL2 you have to use DATAMATE program.

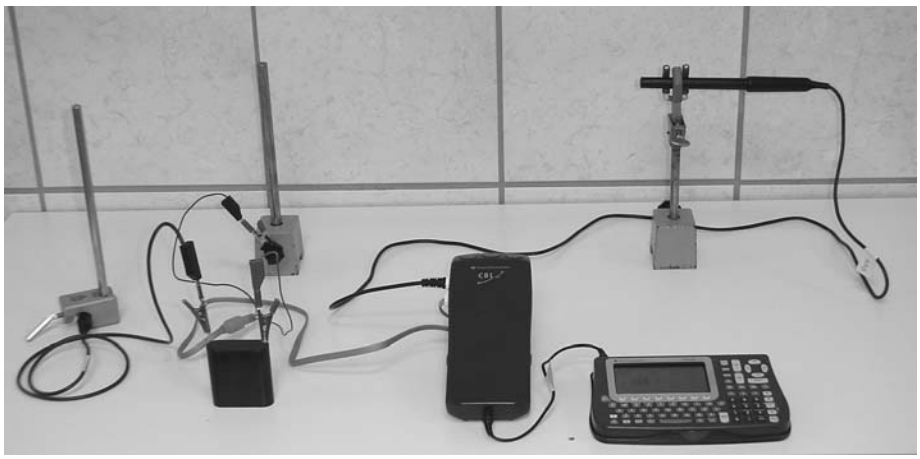
settings in DATAMATE

Data are recorded in TIME GRAPH mode. The following settings are recommended:



Settings of trigger to start the experiment:
Set trigger on channel *2* .
Activate *Increasing* (for the level in volt).
Set *Trigger Treshold* on *0,8* .
Set *Prestore in Percent* on *50* .

photo of set-up

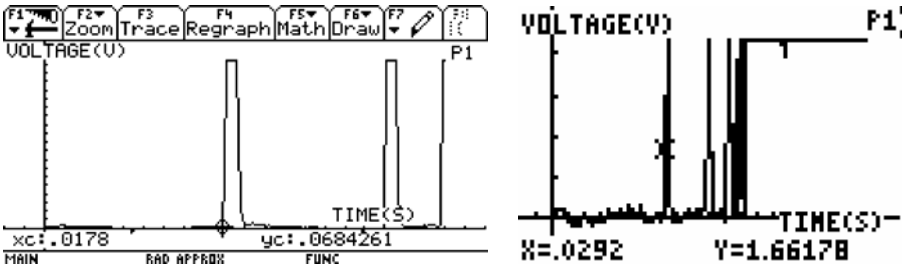


1.1b Measurement of sonic speed in the air – example

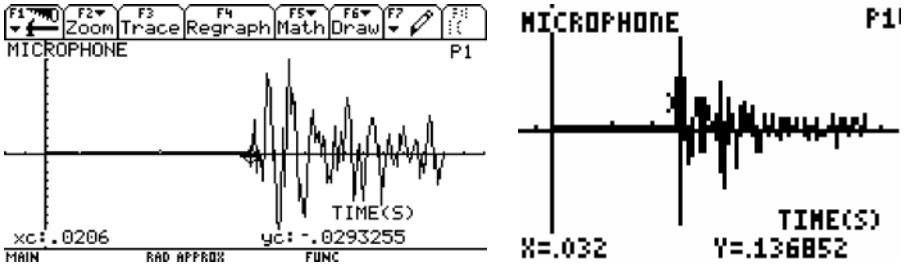
example

The following values were measured by the represented set-up. Micro and rod S1 were at a distance of 97 centimetre.

voltage sensor



microphone



evaluation

Voltage increases for the first time at point in time t_1=0,0178sec (resp. t_1=0,0292sec). At this moment the rod S2 touches the rod S1 and by that closes voltage circuit. The bang is recorded for the first time at point in time t_2=0,0206sec (resp. t_2=0,032sec) by the micro. According to measured values sonic speed in the air is:

$$v_{\text{Luft}} = \frac{d}{\Delta t} = \frac{d}{t_2 - t_1} = \frac{0{,}97\,\text{m}}{0{,}0206\,\text{sek} - 0{,}0178\,\text{sek}} \approx 346\,\tfrac{\text{m}}{\text{s}}$$

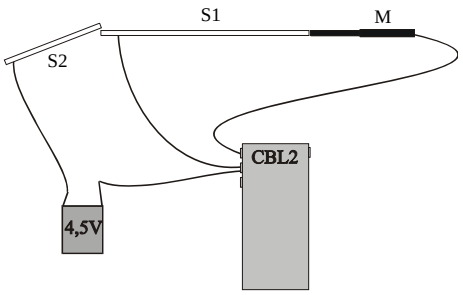
resp.

$$v_{\text{Luft}} = \frac{d}{\Delta t} = \frac{d}{t_2 - t_1} = \frac{0{,}97\,\text{m}}{0{,}032\,\text{sek} - 0{,}0292\,\text{sek}} \approx 346\,\tfrac{\text{m}}{\text{s}}$$

Measured sonic speed in the air is positioned within the framework of known values in literature.

1.2a Measurement of sonic speed in metals – information

schematic set-up

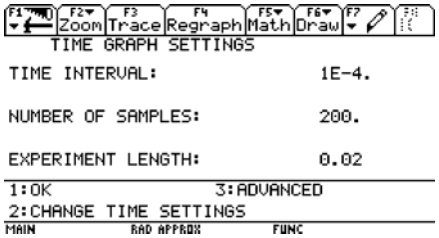


progression of experiment

An electric circuit is built by voltage sensor with two rods (S1 und S2), block battery and the CBL2 (channel 2). The sound (bang) is produced by the student, who smashes with the rod (S1) on footpoint of rod (S2). Closing the electric circuit you can measure voltage at CBL 2. The experiment can be started by triggering the measured voltage. The micro records sound signals parallel to voltage. The rod S1 has to be adjusted, that only a slit of a few millimetre is left between the rod and the capsule of the micro.To communicate with the CBL2 you have to use DATAMATE program.

settings in DATAMATE

Data are recorded in TIME GRAPH mode. The following settings are recommended:



Settings of trigger to start the experiment:
Set trigger on channel *2* .
Activate *Increasing* (for the level in volt).
Set *Trigger Treshold* on *0,8* .
Set *Prestore in Percent* on *50* .

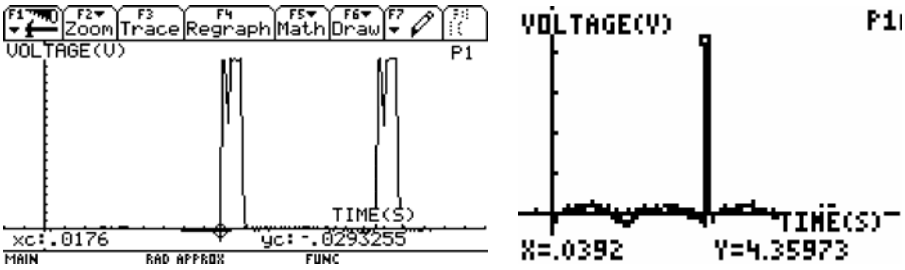
photo of set-up

1.2b Measurement of sonic speed in metals – example

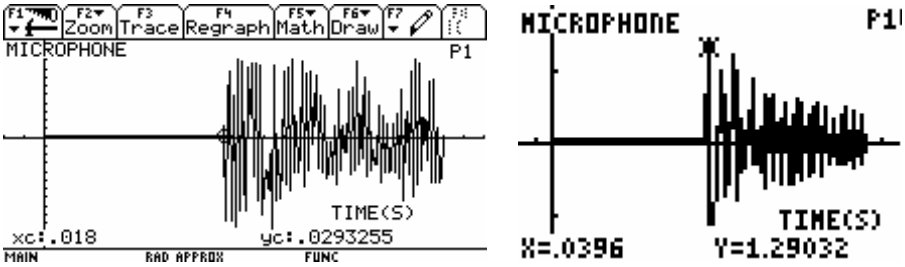
example

The following values were measured by the represented set-up. Rod S1 had a length of 1 metre at the measurement.

voltage sensor



microphone



evaluation

Voltage increases for the first time at point in time t_1=0,0176sec (resp. t_1=0,0392sec). At this moment the rod S2 touches the rod S1 and by that closes voltage circuit. The bang is recorded for the first time at point in time t_2=0,018sec (resp. t_2=0,039sec) by the micro. According to measured values sonic speed in the air is:

$$v_{\text{Luft}} = \frac{d}{\Delta t} = \frac{d}{t_2 - t_1} = \frac{1\,\text{m}}{0,018\,\text{sek} - 0,0176\,\text{sek}} \approx 2500\,\tfrac{\text{m}}{\text{s}}$$

resp. $$v_{\text{Luft}} = \frac{d}{\Delta t} = \frac{d}{t_2 - t_1} = \frac{1\,\text{m}}{0,0396\,\text{sek} - 0,0392\,\text{sek}} \approx 2500\,\tfrac{\text{m}}{\text{s}}$$

Measured sonic speed in metals is positioned within the framework of known values in literature.

hint

The degree of accuracy is restricted by the resolving power of the CBL2. Therefore we think that an estimated fault about 20% measuring sonic speed in metals with proposed methods is relistic. To study qualitatively in teaching precision of measurements seems to be sufficient from our point of view. By making use of longer rods precision can be increased.

1.3a Measurement of sonic speed in the air – students material (1)

in general

If an airoplane is faster than sonic, it will break through the sonic barrier and there will be a loud bang. But how fast is sonic, actually? You can measure sonic speed.

To memorize: if a body or signal moves equable (at constant direction and velocity), you will be able to calculate his velocity using the quotient of distance and time:

$$v = \frac{s}{t} \qquad [Geschwindigkeit] = \frac{[Weg]}{[Zeit]}$$

previous experiment-description

You need two billets and a stop watch. Place two students at a distance of 200 metres. One student takes both billets and strikes them together. The other starts the stop watch, when he notices that the billets strike together. The moment he can hear the bang, he stops it. Repeat this experiment for several times.

previous experiment -questions

Why is it possible to measure time with this experiment? How can you calculate sonic speed using these values?

previous experiment -order

performing this experiment for several times, you have to calculate each sonic speed. How exact is the measuring of the experiment? How fast is sonic speed in the air?

experiment

For some applications (e.g. a Delay PA; look at applications) you need the exact sonic speed, which varies, depending on temperature, humidity, etc. Therefore you will seldom measure the same velocity at different days. For the experiment you need:

needed materials

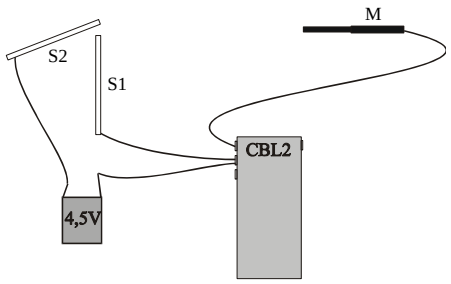
diverse tripod material ,

4,5 volt block battery or other voltage source (adjust 4,5 v)

cable and alligator clips

CBL2
CBL–microphone
CBL–voltmeter (supplied clips)
alternative: **TI83plus**; TI84plus; TI92+; TI89; **TI Voyage 200**

schematic set-up



distance S1 to M: 0,90 m

questions of comprehension

Why is it possible to measure sonic speed with this experiment (hint: light and electric current have nearly the same velocity). What kind of

measuring results do you expect? How can you calculate sonic speed with these measured values?

1.3b Measurement of sonic speed in the air – students material (2)

in general

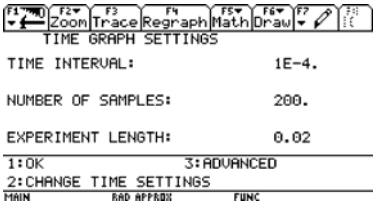
For this instruction you are suggested to have finished basic practical course. If you can`t remember some basic settings, you can use the short descriptions. They will help you to remember.

progression of experiment

An electric circuit is built by voltage sensor with two rods (S1 und S2), block battery and the CBL2 (channel 2). The sound (bang) is produced by the student, who smashes with the rod (S1) on footpoint of rod (S2) – force is not necessary! Closing the electric circuit you can measure voltage at CBL 2. The experiment is started by exceeding a special measured voltage. The micro records sound signals parallel to voltage. To communicate with the CBL2 you have to use DATAMATE program.

settings in DATAMATE

Data are recorded in TIME GRAPH mode. The following settings are recommended:



Settings of trigger to start the experiment:
Set trigger on channel *2* .
Activate *Increasing* (for the level in volt).
Set *Trigger Treshold* on *0,8* .
Set *Prestore in Percent* on *50* .

task 1

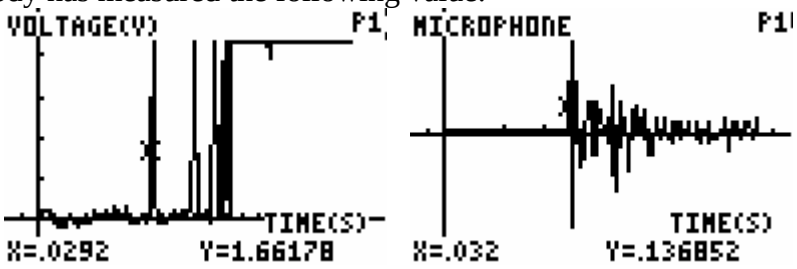
Perform this experiment for several times and determine each sonic speed..

task 2

Compare these values with the values of the previous experiment. Which measurement is more exact? Justify your thesis! Is it possible to increase precision?

task 3

Somebody has measured the following value:



Determine sonic speed for this case (*s*=97cm) and compare it with your own values. In which measurement was it warmer? Plan an experiment to prove the change of sonic speed during varying temperatures.

task 4

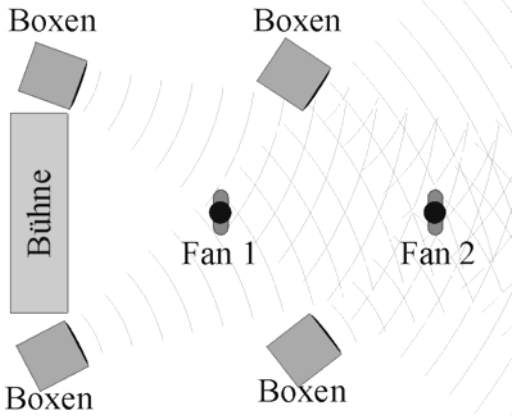
The experiment can be enlarged in a way, which enables you to determine velocity in metals and other materials. Sonic speed measurements of this kind are used for many applications (compare applications). Enlarge the experiment accordingly and implement it.

1.4 Applications of sonic speed measurement

1.4a Public address at big concerts

the problem

At big concerts it is often not sufficient to place loudspeakers only near to the stage. Therefore loudspeakers are also placed in the auditorium:



Would you give the same signal to all loudspeakers, fan 2 would hear an echo, because he hears the sound of the rear speakers at first and after that the sound of the front speakers.

solution

For this problem we have a simple but elegant solution. You can delay the signal electronically. If you know sonic speed, you only have to measure the distance between the front and the rear speakers. The difference of run time is easy to calculate. A problem of shielding, which is hard to solve, is that fan 1 also hears an echo (pay attention at your next pop concert!).

1.4b Clinical diagnosis of trees

the problem

You often can`t recognize, that trees are ill or even rotten. Then, even a little thunder-storm is sufficent to bring down weak trees. Trees at the roadside are very nice, but now they become dangerous. To avoid damaging trees if possible, you need a method to measure the condition without damaging. Like gases and metals all kinds of wood have different speed of sound propagation. This phenomenon can be used helpfully.

solution

You have to measure velocity in the trunk, so you can conclude from comparison to the inside of the tree. With this technique you can diagnoss sickness early and trees can be cut down specifically.